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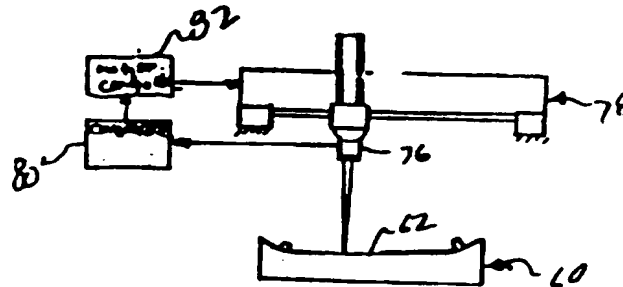
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(54) **PROCEDE ET APPAREIL DE PRE-INCISION LASER**
(54) **LASER SCORING PROCESS AND APPARATUS**



(57) La présente invention vise un procédé et un appareil utilisés aux fins de la pré-incision de pièces à usiner d'épaisseur et/ou de forme variable. L'épaisseur de la pièce à usiner est tout d'abord déterminée en certains points le long d'un tracé, puis une rainure de profondeur variable est formée par pré-incision laser contrôlée en fonction de valeurs d'épaisseur préalablement établies. Ces valeurs peuvent être obtenues par balayage de faces opposées, notamment la face d'un élément de positionnement et la face de la pièce à usiner. Le balayage et la pré-incision sont effectués au moyen de manipulateurs robotisés. La puissance du laser et/ou la vitesse de traçage sont commandées de manière à modifier le degré de pré-incision. Cette technique de pré-incision s'avère particulièrement utile pour l'affaiblissement préalable de garnitures d'automobiles en vue de pratiquer une ouverture pour le déploiement d'un coussin gonflable.

(57) Process and apparatus for precision scoring a workpiece of variable thickness and/or shape in which the thickness of the workpiece at points along a trace pattern is first determined, and a variable depth groove is thereafter formed by laser scoring which is controlled in correspondence with the previously determined thickness values. These values can be determined by scanning opposite surfaces on the surface of a locating fixture and a surface of the workpiece. Robot manipulators are used for scanning and scoring, and the power of the laser and/or the trace velocity are controlled to vary the degree of scoring. The scoring is used to special advantage for precision preweakening of auto trim pieces for creating an air bag deployment opening.

ABSTRACT OF THE DISCLOSURE

Process and apparatus for precision scoring a workpiece of variable thickness and/or shape in which the thickness of the workpiece at points along a trace pattern is first determined, and a variable depth groove is thereafter formed by laser scoring which is controlled in correspondence with the previously determined thickness values. These values can be determined by scanning opposite surfaces on the surface of a locating fixture and a surface of the workpiece. Robot manipulators are used for scanning and scoring, and the power of the laser and/or the trace velocity are controlled to vary the degree of scoring. The scoring is used to special advantage for precision preweakening of auto trim pieces for creating an air bag deployment opening.

LASER SCORING PROCESS AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part to copending application U. S. Serial No. 08/332,565, filed on October 31, 1994.

BACKGROUND OF THE INVENTION

This invention concerns laser scoring in which a laser beam is used to score the surface of material, as to create a line of preweakening.

It has previously been proposed to create a preweakening of a trim piece to allow a deployment "door" to be formed by the pressure of an inflating air bag causing a covering as a layer of vinyl plastic to rupture in a desired pattern to form an opening allowing the air bag to deploy into the passenger compartment from a storage canister behind the trim piece.

This construction is useful for so-called invisible seam construction installations particularly for passenger side, in which the location of the air bag is concealed by the absence of any externally perceptible suggestion of a deployment opening.

The use of the pressure generated by the inflating air bag to rupture the covering skin requires that a precisely controlled preweakening of the covering be carried out.

The air bag must perform reliably over a wide range of ambient temperature conditions. The strength and elongation characteristics of the covering layer, typically of a tough plastic such as vinyl or leather, JPO, TPE, or TPU, varies considerably with ambient temperature. If the covering layer presents too much resistance to rupture, proper deployment of the air bag may not occur due to the resulting delay in overcoming resistance of the covering layer.

At the same time, the preweakened covering must retain sufficient strength so as to not crack or show the line of preweakening on the passenger side.

Covering layers, particularly when made of cast plastic,

1 typically are of irregular thickness due to the inherent lack of
2 precision of the manufacturing process. This variation in
3 thickness makes it difficult to execute preweakening by scoring, as
4 a scored groove of constant depth will result in an erratic
5 preweakening at points along the door pattern since the thickness
6 of the remaining material will vary.

7 This in turn causes erratic air bag performance due to
8 variations in the precise moment when the air bag will burst
9 through the covering layer.

10 Production in the automotive field involves large numbers of
11 parts and such air bag system components should desirably have a
12 very low defect rate, i.e., one part per million or less so as to
13 be consistent with current standards.

14 The object of the present invention is to provide processes
15 and apparatus for precision laser scoring of workpieces which are
16 of varying thickness.

17 SUMMARY OF THE INVENTION

18 This object, as well as others, which will be understood upon
19 a reading of the following specification and claims are achieved by
20 a sensor arrangement which scans the opposite surfaces of a
21 workpiece in a predetermined scoring pattern at a selected location
22 in order to generate coordinate data from which the material
23 thickness can be determined at each point along the pattern.

24 Corresponding data is stored in a computer memory and a
25 control program for a scoring laser is generated in which the
26 tracing speed and/or power intensity of the scoring laser beam are
27 varied at points along the scoring pattern so as to vary the depth
28 of the groove in proportion to the material thickness at each point
29 to create a desired (defining a tear seam) thickness of remaining
30 material along the pattern to insure a precisely controlled
31 preweakening of the sheet material along the pattern.

32 The groove pattern is scanned after the scoring operation to
33 confirm the thickness of the tear seam at each point along the
34 pattern.

1 The prescoring scanning may be carried out by laser beam
2 gaging moved relative the workpiece to trace the scoring pattern on
3 opposite surfaces of the workpieces to generate coordinate
4 measurements of the opposite surfaces at each point along the
5 pattern, from which are derived a record of the material thickness
6 at each point along the pattern.

7 Multiaxis robot manipulator devices can be employed to cause
8 the sensors and/or the scoring lasers to trace the pattern on the
9 workpiece. The scanning sensors can be mounted to a single robot
10 so that the movement for prescanning, scoring, and post process
11 inspection is carried out simultaneously in a single station.
12 These steps can also be carried out by multiple passes or by
13 separate robot manipulators in two separate stations.

14 In the two station setup, the workpiece and the fixturing
15 therefore is shuttled between gaging and scoring stations with
16 suitable locator mechanisms or reference fiducials employed to
17 precisely determine the relative workpiece position in each
18 station.

19 In one alternative, the workpiece is precisely positioned in
20 a fixture as by being vacuum held therein. Initially, prescanning
21 the fixture surface in the scoring pattern is carried out to
22 develop corresponding data. Subsequently, the workpiece is clamped
23 in the fixture and scanned in the same trace pattern. The
24 workpiece thickness along the pattern can then be determined to
25 develop the laser scoring power/speed control program.

26 In yet another alternative, the fixture can be scanned in the
27 predetermine scoring pattern. The scoring laser is then
28 controllably displaced preferably normal to the workpiece surface
29 as it is traced along the pattern with the workpiece in place on
30 the fixture so as to locate the focal point of the laser beam at a
31 constant distance above the scanned fixture surface. This results
32 in a variable scoring depth, but a constant thickness of remaining
33 material since the laser beam will cut away all material in its
34 path above its focal point.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a fragmentary, perspective view of an instrument panel and air bag device having a covering which is preweakened by scoring in a pattern corresponding to the air bag deployment opening.

Figure 1A is an enlarged sectional view of a portion of the instrument panel shown in Figure 1.

Figure 1B is a further enlarged view of a portion of the section shown in Figure 1A.

Figure 2 is a diagrammatic representation of a workpiece scanning apparatus for developing a record of the workpiece thickness along a pattern to be scored therein.

Figure 2A is a diagrammatic representation of laser scoring apparatus for carrying out the scoring of the workpiece using the thickness data developed in the prior scanning operation.

Figure 3 is an enlarged diagram of the covering indicating the material thickness groove.

Figure 4 depicts a cast covering layer workpiece to be scored.

Figure 4A is a diagrammatic representation of a scanning apparatus for an alternative process for determining the thickness of the workpiece along the scoring pattern, particularly suited for a cast covering layer.

Figure 4B is a diagrammatic representation of a second stage scanning apparatus to carry out the alternative process.

Figure 4C is a diagrammatic representation of scoring apparatus to be used in the alternative method.

Figure 5 is a diagrammatic representation of apparatus for simultaneously scanning opposite surfaces of a workpiece.

Figure 6 is a diagrammatic representation of apparatus for carrying out another alternative process for carrying out workpiece scoring, depicting prescoring scanning of a fixture used to locate the workpiece.

Figure 6A is a diagrammatic representation of apparatus for carrying out the process of precision scoring of a workpiece, using data developed by the apparatus of Figure 5.

1 Figure 7 is a perspective view of preferred apparatus for
2 carrying out the preferred process for precision scoring of a
3 workpiece, also shown in Figure 7.

4 Figure 8 is a fragmentary perspective view of a portion of a
5 robot manipulator showing an alternate configuration.

6 Figure 9 is a fragmentary perspective view of a portion of a
7 robot manipulator showing another alternative configuration.

8 DETAILED DESCRIPTION

9 In the following detailed description, certain specific
10 terminology will be employed for the sake of clarity and a
11 particular embodiment described in accordance with the requirements
12 of 35 USC 112, but it is to be understood that the same is not
13 intended to be limiting and should not be so construed inasmuch as
14 the invention is capable of taking many forms and variations within
15 the scope of the appended claims.

16 Referring to the drawings and particularly Figures 1, 1A, and
17 1B, a portion of an instrument panel 14 is shown along with a
18 portion of an automotive vehicle 10 having a passenger compartment
19 12. The instrument panel 14 has a covering 16 which is preweakened
20 in an H-pattern 18 such as to enable the formation of a pair of
21 doors 20 and 22, which when open form a deployment opening for an
22 air bag device 24 mounted behind the instrument panel 14 and
23 aligned with the deployment opening to be formed by opening of the
24 door panels 20 and 22.

25 The preweakening pattern 18 is invisible from the passenger
26 space 12, being defined by a scoring 26 on the undersurface of the
27 covering layer 16 as best seen in Figure 1B. The pattern shown is
28 for a double door deployment opening. A U-shaped pattern is
29 employed for single doors and various patterns including an X-
30 pattern is contemplated for four door deployment openings.

31 The deployment opening is created at the moment of inflation
32 of the air bag cushion 28, the force exerted by the inflating air
33 bag cushion on the inside of the door panels 20 and 22 creating a
34 pressure, such as to cause the covering 16 to rupture in the H-

1 pattern 18. This allows an outward hinging of the deployment door
2 panels 20, 22 and to thereby form the air bag deployment opening.

3 Various constructions of the trim pieces, i.e., instrument
4 panel 14, are known which typically involve a foam layer 30
5 underlying the covering 16. The covering 16 provides an
6 aesthetically pleasing surface exposed to view within the passenger
7 compartment 12.

8 Other currently utilized trim piece constructions which can be
9 preweakened in the same manner are hard plastic, vinyl cladding
10 over hard plastic, and the above-described skin and foam.

11 As discussed above, the scoring 26 is preferably carried out
12 so as to achieve a precisely controlled preweakening. Too shallow
13 scoring will result in the too high resistance of the covering
14 layer bursting. The covering 16 is typically of a tough plastic
15 such as vinyl, so that minor variations in tear seam thickness will
16 interfere with the proper deployment of the air bag.

17 If the scoring 26 is too deep, this may result in marring of
18 the external appearance of the instrument panel 14 or vulnerability
19 to splitting particularly when subjected to external pressure
20 exerted by incidental contact with the instrument panel surface,
21 long-term sun and/or heat exposure.

22 Figures 2 and 2A illustrate the basic concept of the process
23 of precision scoring of the covering 16. The covering 16 may be
24 formed by a casting process which has a defined shape prior to
25 being mounted to the remaining components of the instrument panel.

26 The cast covering 16 workpiece is positioned in a suitable
27 fixture 32 with locating features 34 mating with existing openings
28 in the covering 16, such as air conditioning duct outlets.

29 Sensing means is initially utilized to detect the precise
30 thickness of the covering 16 at points along the scoring pattern
31 18. The sensing means illustrated diagrammatically in Figure 2 is
32 comprised of a first sensor 36 and a second sensor 38 which
33 together scan the surface 40 of the skin 16 to be scored as well as
34 the opposite surface 42 on the other side of the covering 16.

35 The sensors 36 and 38 may comprise so-called laser

1 triangulation sensors which are commercially available. These
2 sensors are mounted on manipulator devices 44 and 46, which allow
3 the sensors 36 and 38 to scan the respective surfaces of the
4 covering 16 in the scoring pattern, while maintaining a
5 perpendicularity to the surfaces at each point despite the presence
6 of any curvature or other topographical features of the covering
7 layer 16 at a particular point along the scoring pattern. The
8 manipulator devices 44, 46 comprise mechanisms enabling powered
9 movement along orthogonal axes and tilting of the sensors about
10 each of these axes. Suitable carriage, way, and swivel mount
11 structures are indicated, but multiaxis robot devices such as are
12 commercially available are preferred as described hereinafter.

13 The sensors 36 and 38 transmit coordinate data to a computer
14 48. From this coordinate data, the thickness of the covering layer
15 16 at each point along the scoring pattern 18 may be determined.

16 The computer 48 may also be used to operate a motion
17 controller 50 which causes the manipulator devices 44 and 46 to
18 execute the necessary motions to scan the scoring pattern.

19 The thickness data so derived is utilized as indicated in
20 Figure 2A in controlling a scoring laser 52 which is likewise
21 mounted for manipulation by a manipulator device 54 so as to be
22 able to trace the scoring pattern 18 to carry out the scoring of
23 the inside surface 40 of the covering layer workpiece 16. A
24 suitable motion capability of the manipulator device should be
25 provided to allow a distance above the workpiece to be maintained.

26 A suitable motion controller 56 utilized for this purpose is
27 operated by the computer 48 and suitable motion programming as is
28 used with commercial robot manipulators.

29 An empirically developed "lookup" table can be provided which
30 consists of a set of data in which the correlation among a power
31 density of the scoring laser 52 and the speed of the manipulator
32 device corresponding depth of groove scoring is listed. This data
33 is correlated with the thickness data determined in the scanning of
34 the covering skin workpiece in the scoring pattern 18 so as to
35 select the power intensity level necessary to remove material to a

1 depth sufficient to leave a desired thickness of material remaining
2 after the scoring has been completed at each point along the
3 scoring pattern 18 at each point.

4 This is indicated in Figure 3 where the overall thickness t_0 ,
5 t_{02} , t_{03} determines the depth of the groove t_1 , t_2 , t_3 at these points
6 so as to result in a desired remaining material thickness tr_1 , tr_2 ,
7 tr_3 at various points along the trace pattern 18.

8 The scoring depth may also be controlled by varying the
9 velocity of movement of the laser beam along the trace pattern 18
10 with a constant power level, in which case the motion controller 56
11 creates a varying velocity of movement of the scoring laser 52 as
12 it traces the pattern along the scoring pattern 18.

13 Combinations of laser power density and trace velocity are
14 also a possibility.

15 Suitable computer software for carrying out such laser control
16 are available from Servo Robot, Inc. of Boucherville, Quebec,
17 Canada and who also offers suitable scanning triangulation sensors
18 such as are contemplated for the first and second sensors 36 and 38
19 indicated and depicted diagrammatically in Figure 2.

20 It is also possible to cause the trace scanning and scoring of
21 the lasers and sensors by means of optical systems which steer the
22 laser beams.

23 Figure 4 indicates a so-called 1st covering layer 16 which is
24 molded within a mold 58 under which process is not carried out
25 under pressure such that considerable variation in the material
26 thickness of the covering layer 16 is typically encountered.

27 The covering layer 16 when cast has particular contours.
28 Figures 4A-4C depict diagrammatically a variation of the process
29 shown in Figures 2 and 2A suited particularly to such cast covering
30 layer workpieces.

31 A fixture 60 has an inner contour 62 shaped to receive the
32 workpiece 16. The contour 62 is initially scanned at the
33 particular location of the trace pattern 18 along the path of the
34 trace pattern such as to develop coordinate electronic signals
35 corresponding to the coordinates in space of the surface 62 of the

1 fixture 60 at points along the trace pattern 18.

2 Locating features 64 are provided on the fixture 60. Also
3 provided is a suitable hold-down such as a vacuum holder defined by
4 a pattern of holes 66 communicating with a passage 68 connected to
5 vacuum pump 70 for purposes that will be described hereinafter.

6 The tracing may be carried out by a triangulation gaging laser
7 76 mounted on a motion manipulator device 78 which allows tracing
8 of the pattern on the surface 62.

9 The electronic signals corresponding to the coordinate data
10 are transmitted to a computer 80 which may also operate the motion
11 controller for the manipulator device 78.

12 The workpiece 16 is then placed in the fixture 60 in a vacuum
13 chucking arrangement, which when activated acts to pull the
14 opposite surface 42 of the covering layer 16 firmly against the
15 surface 62 of the fixture 60. The scanning laser 76 is then
16 operated to scan the inner surface 40 of the workpiece 16 at points
17 along the trace pattern 18, which coordinate data is transmitted in
18 the form of electronic signals to the computer 80 which again may
19 control the motion controller 82 for the manipulator device 78
20 using commercially available software.

21 Two sets of data corresponding to the fixture surface 62 and
22 the covering layer surface 40 allow determination of the thickness
23 of the covering layer precisely at points along the trace pattern
24 18, which thickness data is stored in the computer 80.

25 Figure 4C shows a scoring laser 84 caused to trace the same
26 pattern 18 by means of a manipulator device 85 to carry out scoring
27 of the inner surface 40 of the covering layer 16. The depth of the
28 groove is controlled by laser controller 86 which in turn receives
29 commands from the computer 80. Command signals from the computer
30 80 combine the thickness information for each point along the trace
31 pattern 18 and laser power data contained in a lookup table 88.
32 This data may as before correlate the power density of the scoring
33 laser 84 with the depth of groove produced in a particular material
34 of the covering workpiece 16 such as to create a score depth at
35 each point along the trace pattern 18 calculated to leave a desired

1 remaining thickness of material at each point along the trace
2 pattern on the covering layer workpiece 16.

3 As before the computer 80 may be utilized to operate a motion
4 controller 90 for the manipulator device 86. As before, the
5 computer 80 can also be utilized to operate the motion controller
6 82 for executing the motion of the scoring laser 84 so as to trace
7 the pattern 18 while maintaining perpendicularity and desired
8 spacing above the surface of workpiece 16. Thus, combinations of
9 variations in the power density in the laser beam and the velocity
10 of the trace movement can be utilized to control the depth of the
11 groove scored into the surface 40 of the cover layer 16 workpiece.

12 The vacuum holding insures that the opposite surface 42 of the
13 covering layer 16 is held in tight contact with the surface 62 of
14 the fixture 60 such that there is a close correlation in the
15 thickness as calculated using the coordinate data of the surface 62
16 and the surface 40 of the covering layer 16, such as to provide
17 accurate control over the depth of the scoring.

18 Figure 5 indicates diagrammatically that the sensors 36 and 38
19 can be connected together with a U-shaped structure 61 to be moved
20 simultaneously. It is noted that the fixture 32 must be slotted
21 along the trace pattern 18 to allow sensing of the undersurface 42
22 of cover 16.

23 Figures 6 and 6A illustrate yet another alternative in which
24 the surface 62 of the fixture 60 is scanned as before by the
25 scanning laser 76 to generate coordinate data corresponding to the
26 surface 62 at points along the trace pattern 18 which is
27 transmitted to the computer 80.

28 However, rather than power intensity control, the computer 80
29 is utilized to control the motion controller 90 by a Z axis motion
30 controller 92 which moves the scoring laser 84 vertically along the
31 Z axis so as to maintain the focal point of the laser beam at a
32 fixed distance and perpendicular relative to the surface 62 of the
33 fixture with the workpiece 16 in position on the fixture 60.

34 Since the laser beam will cut all material above the focal
35 point, the groove will be formed down to the location of the focal

1 point of the beam. If the beam focal point is maintained a desired
2 distance, and also preferably perpendicular orientation from the
3 fixture surface 62, a constant thickness of remaining material will
4 result.

5 It should be noted that the particular groove depth and
6 thickness of the material is a matter for specification by the
7 product designer, which specification will vary with the air bag
8 system requirements and the material of the covering layer 16, the
9 geometry of the deployment opening, etc.

10 Such considerations do not form a part of the present
11 invention.

12 Figure 7 shows an actual apparatus and process for scoring a
13 workpiece 96, which is depicted as a cast covering layer, which is
14 placed in a fixture 98 having a locating recess 100 in the
15 workpiece to be received therein. Locating features 102 are also
16 used, as mentioned above.

17 A clamping mechanism 104 is also used to compress the region
18 of the workpiece within which the trace pattern, here indicated as
19 a U-pattern 106, is located.

20 The clamp 104 has a U-shaped cutout so as to allow the laser
21 beam of the sensors and scoring laser generators 112, 116 to access
22 the surface of the fixture 98 as well as the workpiece 96.

23 A vacuum chucking is in the region of the cutout is enabled by
24 a series of openings or holes 108 connected to a vacuum source to
25 press the workpiece to the workpiece fixture surface 100 in the
26 regions immediately adjacent the trace pattern 106.

27 A first station indicated in the center of Figure 7 shows a
28 robot manipulator 110 which mounts a sensing laser generator 112 of
29 the triangulation type mentioned above which is utilized to
30 generate coordinated information at points along the trace pattern
31 106 for both the fixture 98 and the workpiece 96 as in the
32 arrangement depicted diagrammatically in Figures 4A-4C.

33 A second station has a second robot manipulator 114 located to
34 enable scoring along the trace pattern 106 of the inner surface of
35 the workpiece 96. The clamping mechanism 104 is used to compress

1 the region of the workpiece adjacent the trace pattern, here
2 indicated as a U pattern 106.

3 Vacuum holding of the workpiece 96 in the region of the cutout
4 is enabled by a pattern of holes 108 connected to a vacuum source
5 to press the workpiece to the workpiece fixture surface 100.

6 In the regions immediately adjacent the trace pattern 106, a
7 first station indicated in the center of Figure 7, a robot
8 manipulator 110 is located which mounts a sensing laser generator
9 112 of the triangulation type as mentioned above, which is utilized
10 to generate coordinated information at points along the trace
11 pattern 106 for both the fixture 98 and the workpiece 96 as in the
12 arrangement depicted diagrammatically in Figures 4A-4C.

13 A second station has a second robot manipulator 112 located to
14 enable scoring along the trace pattern 106 of the inner surface of
15 the workpiece 96. The clamping mechanism 104 is not shown in the
16 robot stations for a clearer understanding.

17 The scoring laser 116 is controlled to vary the degree of
18 grooving carried out by the scoring laser beam.

19 The workpiece and fixtures are moved downstream to subsequent
20 stations opposite the first gaging station at which the gaging
21 robot manipulator 110 is relocated for post process inspection of
22 the groove formed along the trace pattern 106.

23 The coordinate information concerning the groove can be stored
24 for historical reference in association with each workpiece
25 produced

26 Figure 3 illustrates an arrangement in which a single robot
27 manipulator 118 has a scanning gaging laser generator 120 and a
28 scoring laser 122 both mounted thereon. This arrangement allows
29 the scanning of the trace pattern 106 and subsequent scoring with
30 a single robot such as to carry out both scanning and scoring in a
31 single station, eliminating the need for handling of the workpiece
32 and fixturing from station to station and also the need to locate
33 and recalibrate as each fixture is moved from station to station.

34 In Figure 9, this concept is carried one step further in which
35 a robot manipulator 124 has attached a preprocessing scanning laser

1 generator 126, a laser scoring generator 128 and a post process
2 scanning laser generator 130 so that all three steps can be carried
3 out in a single pass with a single manipulator and at a single
4 station.

CLAIMS

1. Apparatus for precision scoring of a workpiece to preweaken said workpiece in a pattern, said apparatus comprising:
sensor means for sensing the thickness of said workpiece at points along said predetermined pattern and generating a set of stored data corresponding to values of said sensed workpiece thickness at said points along said pattern;

a scoring laser for generating a laser beam capable of scoring a surface of said workpiece;

motion controller means for causing said laser beam to trace said workpiece surface along said pattern; and,

laser control means for controlling the degree of scoring of said workpiece surface at points along said pattern as said laser beam traces said pattern in correspondence with said set of stored data generated by said sensor means so as to score said workpiece in said pattern to a controlled extent along said pattern.

2. The apparatus according to claim 1 wherein said laser control means controls said laser beam so as to vary the depth of scoring of said workpiece to produce a controlled remaining thickness of said workpiece along said scoring pattern.

3. The apparatus according to claim 1 wherein said laser control means controls the power intensity of said laser beam to vary the extent of workpiece scoring.

4. The apparatus according to claim 1 wherein said laser control means varies the velocity with which said scoring laser beam traces said pattern to control the extent of scoring of said workpiece.

5. The apparatus according to claim 1 wherein said laser control means controls the depth location of a focal point of said laser beam relative said workpiece surface to be traced by said

scoring laser beam.

6. The apparatus according to claim 3 wherein said laser control means includes stored power intensity values predetermined to produce a corresponding extent of scoring, and said power intensity values are set in correspondence with said sensed workpiece thickness values to produce a desired thickness of material remaining after scoring.

7. The apparatus according to claim 1 wherein said sensor means includes a first sensor detecting the location of said workpiece scored surface at points along said pattern and generating a corresponding set of stored signals.

8. The apparatus according to claim 7 wherein said sensor means further includes a second sensor detecting the location of a surface of said workpiece opposite said scored surface at points along said traced patterns, and generating a corresponding set of stored signals, and wherein said sensor means combines said stored signals of said first and second sensors to determine said thickness of said workpiece at points along said pattern to be traced.

9. The apparatus according to claim 8 wherein said first and second sensors are connected together and wherein said sensor means includes means driving said first and second sensors together to scan said workpiece along said pattern to be traced by said scoring laser beam.

10. The apparatus according to claim 7 wherein said first sensor comprises a laser gaging sensor generating a gaging laser beam tracing said workpiece surface in said predetermined pattern prior to scoring of said surface by said scoring laser beam.

11. The apparatus according to claim 8 wherein said first sensor comprises a laser sensor generating a gaging laser beam tracing said workpiece surface in said predetermined pattern prior to scoring of said surface by said scoring sensor, and said second sensor comprises a second laser sensor generating a gaging laser beam tracing said opposite workpiece surface in said predetermined pattern.

12. The apparatus according to claim 1 wherein said sensor means includes a sensor carried by said motion control means for said scoring laser to scan said workpiece surface in said pattern just prior to scoring by said scoring laser beam.

13. The apparatus according to claim 1 wherein said apparatus further includes a first station whereat said workpiece is scanned by said sensor means and a second station in a second position, whereat said workpiece surface is scored by said scoring laser beam and also includes means for shifting said workpiece from said first to said second station.

14. The apparatus according to claim 12 further including post scoring sensor means carried by said motion control means for scanning said scoring carried out by said scoring laser beam and generating a stored set of corresponding signals.

15. The apparatus according to claim 7 wherein said apparatus further includes a workpiece fixture having a locating surface receiving a surface of said workpiece opposite said surface to be scored, and wherein said sensor means includes detector means for detecting the location of said fixture surface at points along said pattern to be scored and generating a stored set of corresponding signals.

16. The apparatus according to claim 15 further including means for pressing said workpiece against said fixture locating

surface.

17. A method for precision scoring a surface of a workpiece to preweaken said workpiece in a predetermined pattern, said method comprising the steps of:

sensing the thickness of said workpiece at points along said predetermined pattern and generating a set of stored data corresponding to values of the thickness of said workpiece sensed at said points along said pattern;

generating a laser scoring beam capable of scoring said surface of said workpiece;

causing said laser beam to trace said workpiece surface along said pattern; and,

controlling the scoring effect of said laser beam so as to vary the degree of scoring of said workpiece surface at points along said pattern as said laser beam traces said pattern in correspondence with said set of stored signals generated during said sensing step so as to score said workpiece in said predetermined pattern to a controlled extent at points along said pattern corresponding to said workpiece thickness at each of said points.

18. The method according to claim 17 wherein in said step of controlling the scoring effect of said laser beam, the depth of scoring of said workpiece is varied so as to produce a substantially controlled remaining thickness of said workpiece along said scoring pattern.

19. The method according to claim 17 wherein said step of controlling said laser beam includes the step of varying the power intensity of said laser beam to vary the extent of workpiece scoring.

20. The method according to claim 17 wherein the step of controlling the scoring effect of said laser beam includes the step

of varying the velocity with which said scoring laser beam is caused to trace said pattern to thereby control the extent of scoring of said workpiece.

21. The method according to claim 17 wherein the step of controlling the scoring effect of said laser beam includes the step of varying the depth location of a focal point of said laser beam relative to said workpiece surface to be traced by said scoring laser beam.

22. The method according to claim 19 wherein said step of controlling the scoring effect of said laser beam includes the steps of generating a set of power intensity values predetermined to produce a corresponding extent of scoring of the material of said workpiece, and setting said power intensity values in correspondence with said sensed workpiece thickness stored signal values.

23. The method according to claim 17 wherein said sensing step includes the step of detecting the location of said workpiece surface at points along said pattern and generating a corresponding set of stored signals.

24. The method according to claim 17 wherein said sensing step further includes the steps of detecting the location of a surface of said workpiece opposite said scored surface at points along said traced patterns, and generating a corresponding set of stored signals, and combining said stored signals of said first and second sensors to determine said thickness of said workpiece at points along said pattern to be scored.

25. The method according to claim 14 wherein said method includes the step of sensing the thickness of said workpiece at each point in said pattern just before scoring said workpiece at said point.

26. The method according to claim 23 wherein said sensing step includes the step of generating a gaging laser beam and scanning said workpiece surface along said predetermined pattern prior to scoring of said surface by said scoring laser beam.

27. The method according to claim 24 wherein said sensing step comprises the step of generating a gaging laser beam and tracing said workpiece surface in said predetermined pattern prior to scoring of said surface by said scoring sensor, and generating a second gaging laser beam tracing said opposite workpiece surface in said predetermined pattern.

28. The method according to claim 17 wherein said sensing step includes the step of mounting a sensor carried with said scoring laser so as to scan said workpiece surface in said pattern just prior to scoring by said scoring laser beam.

29. The method according to claim 17 further including the step of shifting said workpiece between a first station whereat said workpiece thicknesses are sensed and a second station in a second offset position, whereat said workpiece surface is scored by said scoring laser beam.

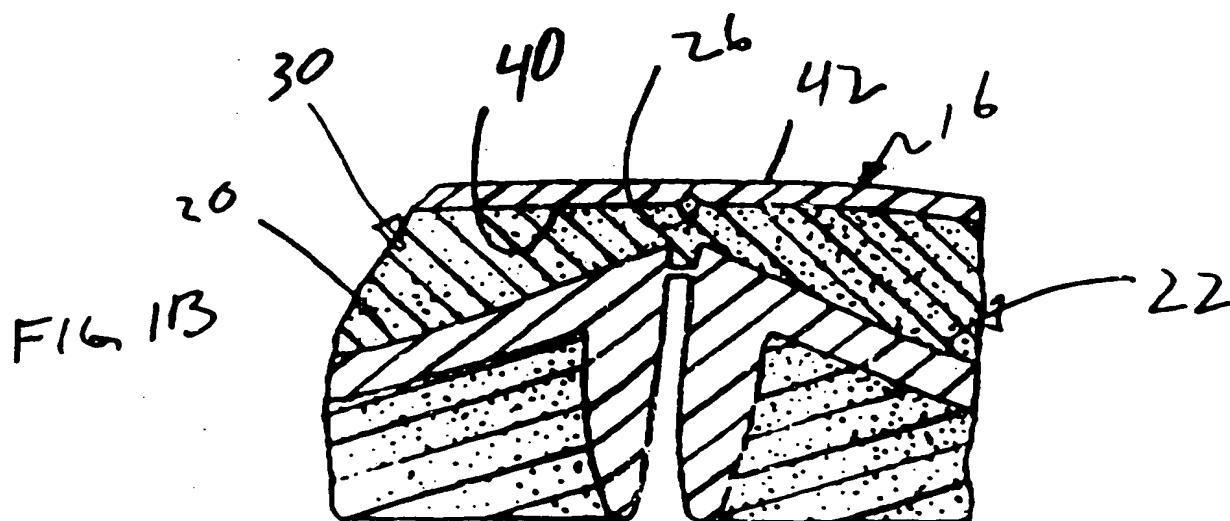
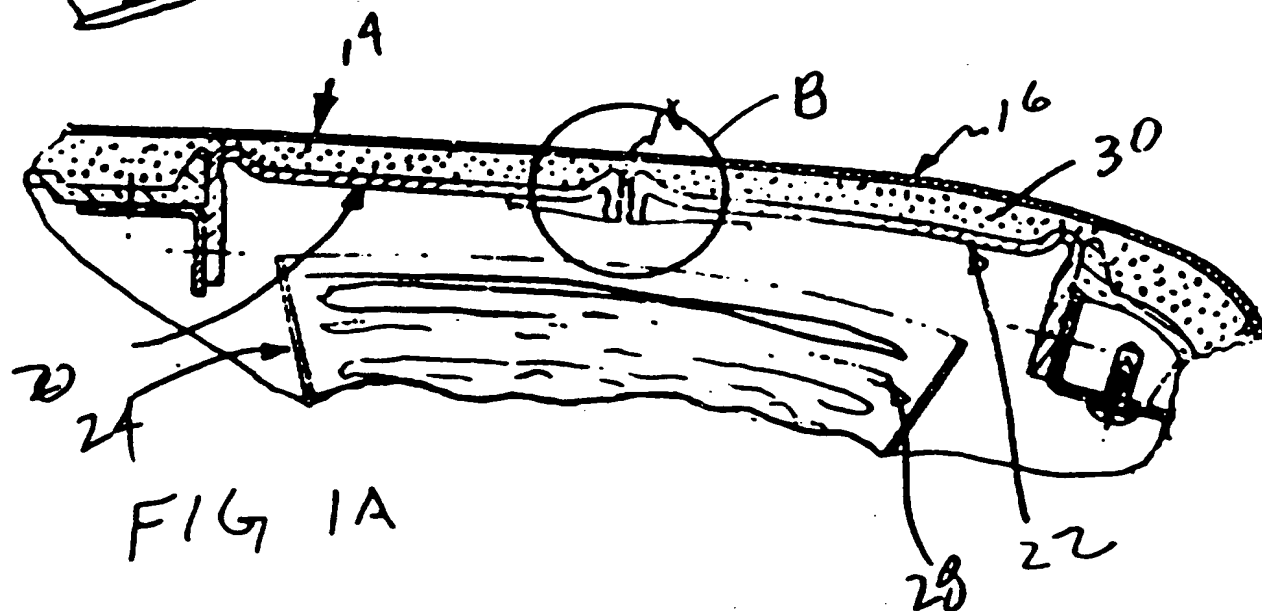
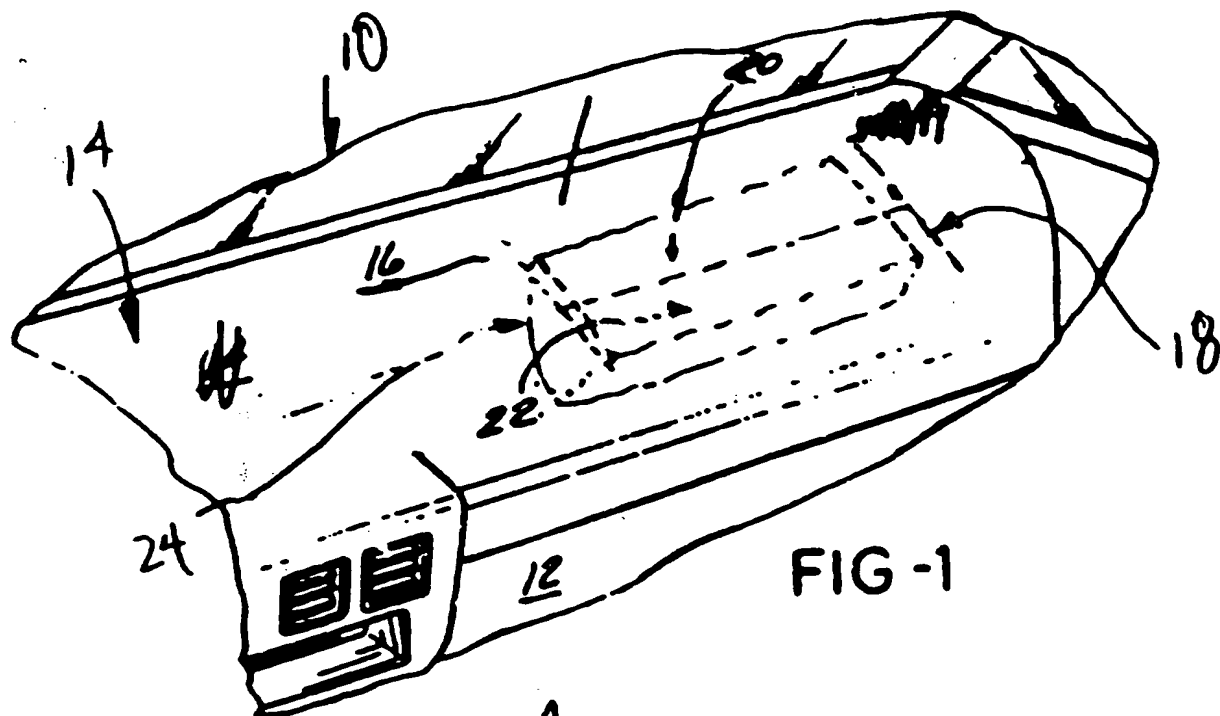
30. The method according to claim 17 further including the step of scanning said scored groove after said scoring is carried out by said scoring laser beam and generating a stored set of data corresponding to the degree of scoring.

31. The method according to claim 23 further including the step of positioning said workpiece in a workpiece fixture having a locating surface against which is abutted a surface of said workpiece opposite said surface to be scored, and further including the step of detecting the location of said fixture surface at points along said pattern to be scored and generating a stored set of corresponding signals.

32. The method according to claim 31 further including the step of pressing said workpiece against said fixture locating surface.

33. The method according to claim 17 wherein said workpiece comprises an interior trim piece used to cover an air bag device, and said scoring is used to preweaken said trim piece to enable formation of an air bag deployment opening.

34. The product produced by the method of claim 17.



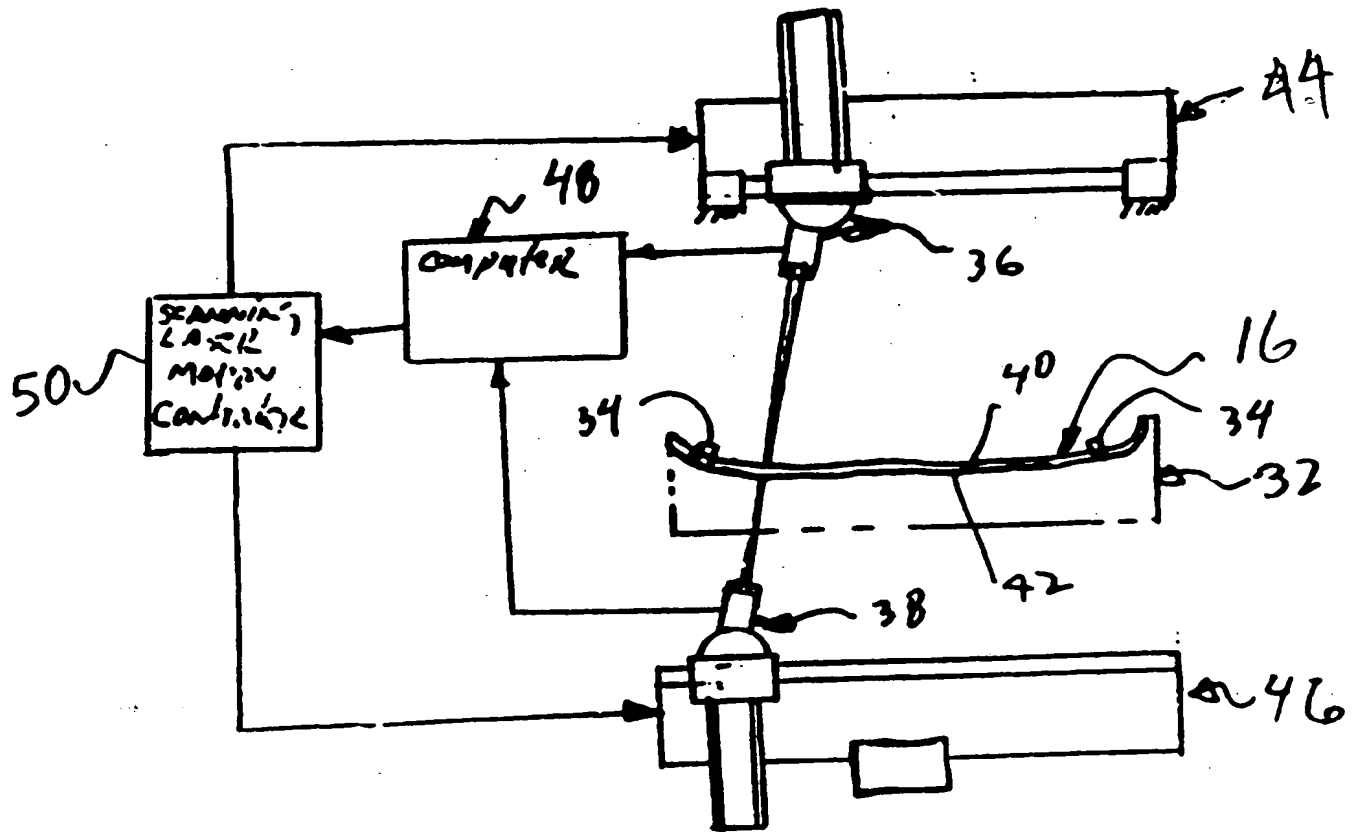


FIG 2

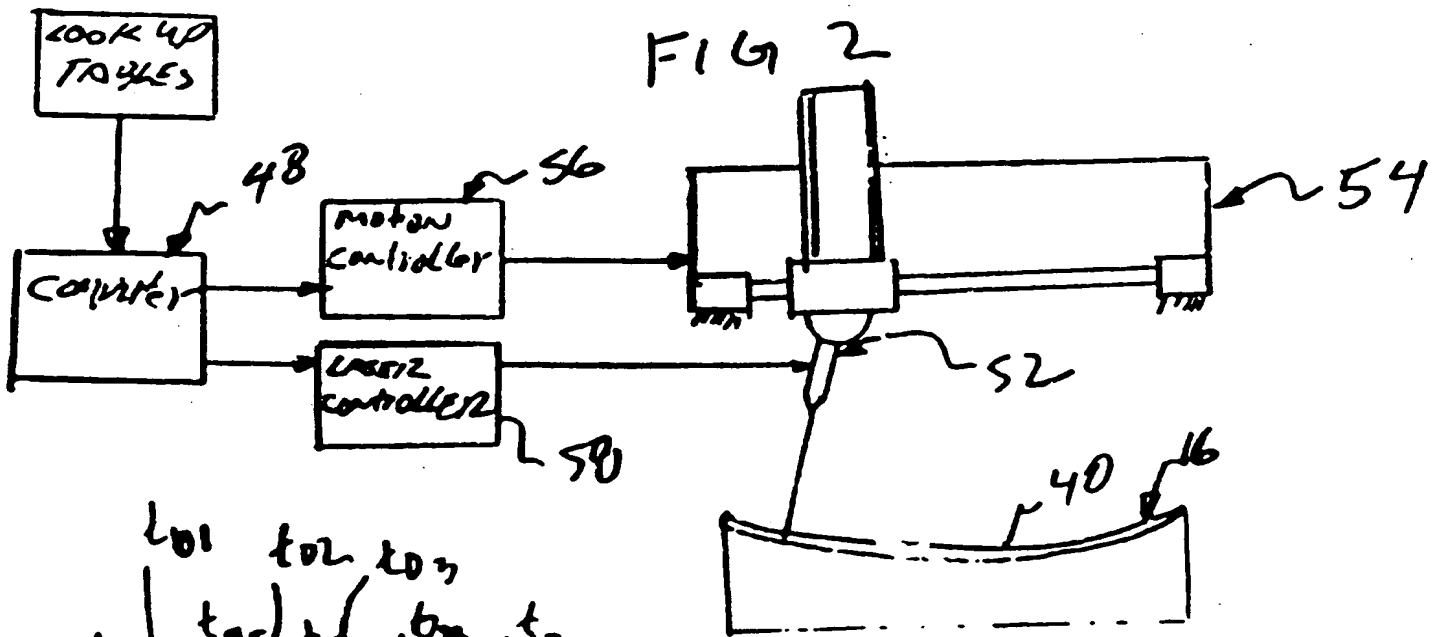
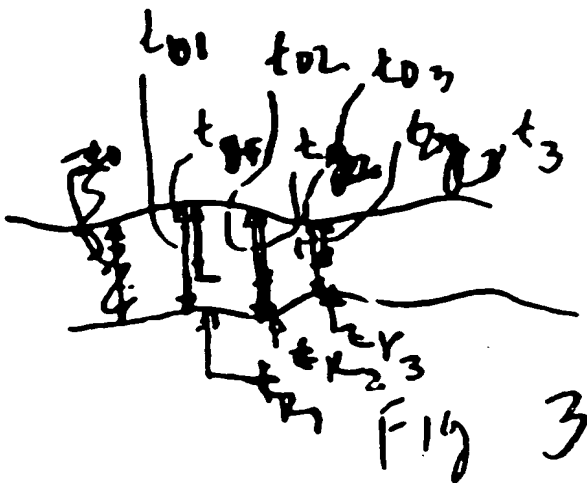


FIG 2A



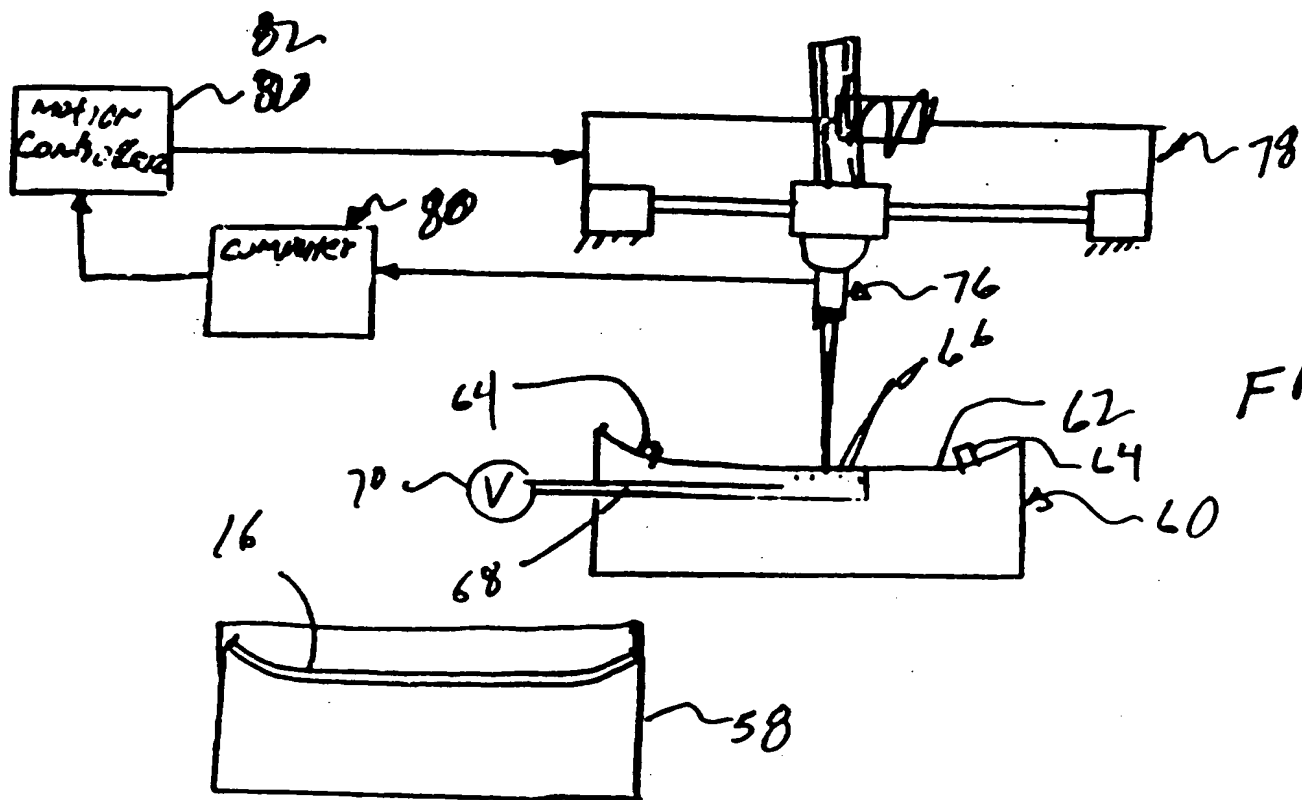


FIG 4A

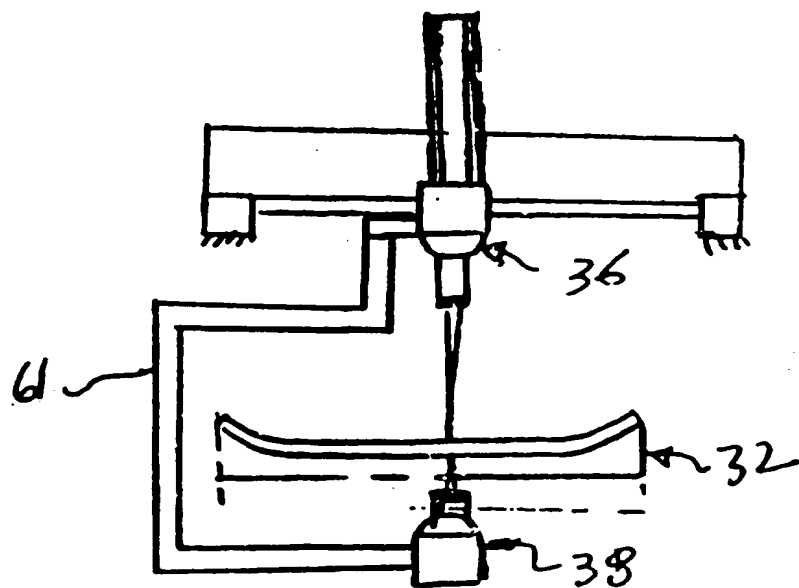


FIG 5

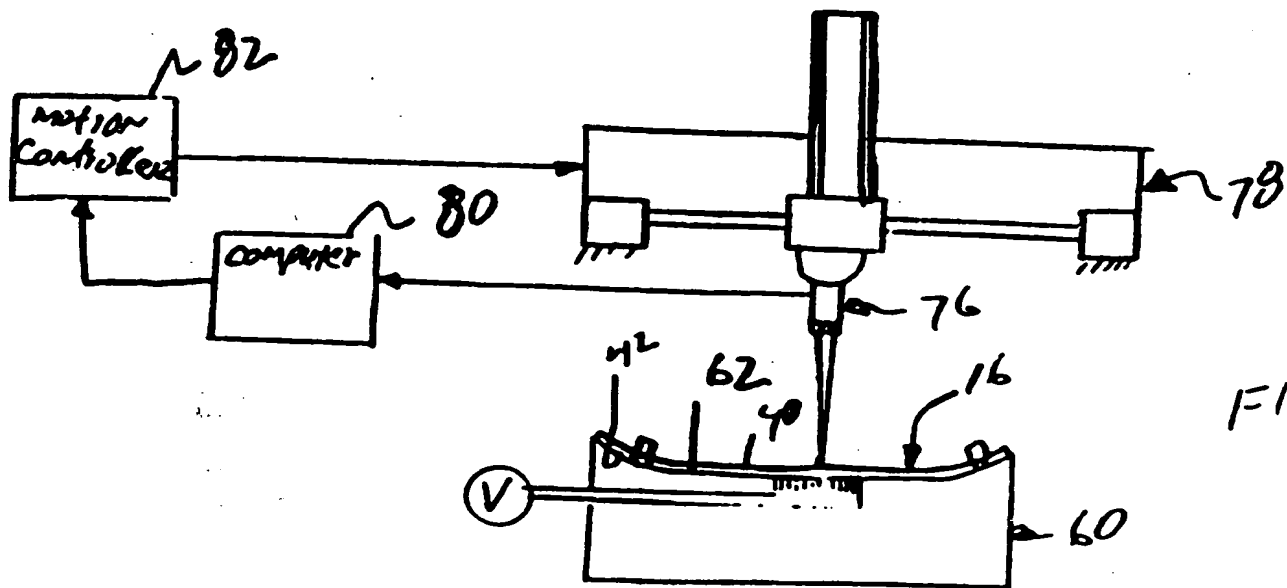


FIG 4B

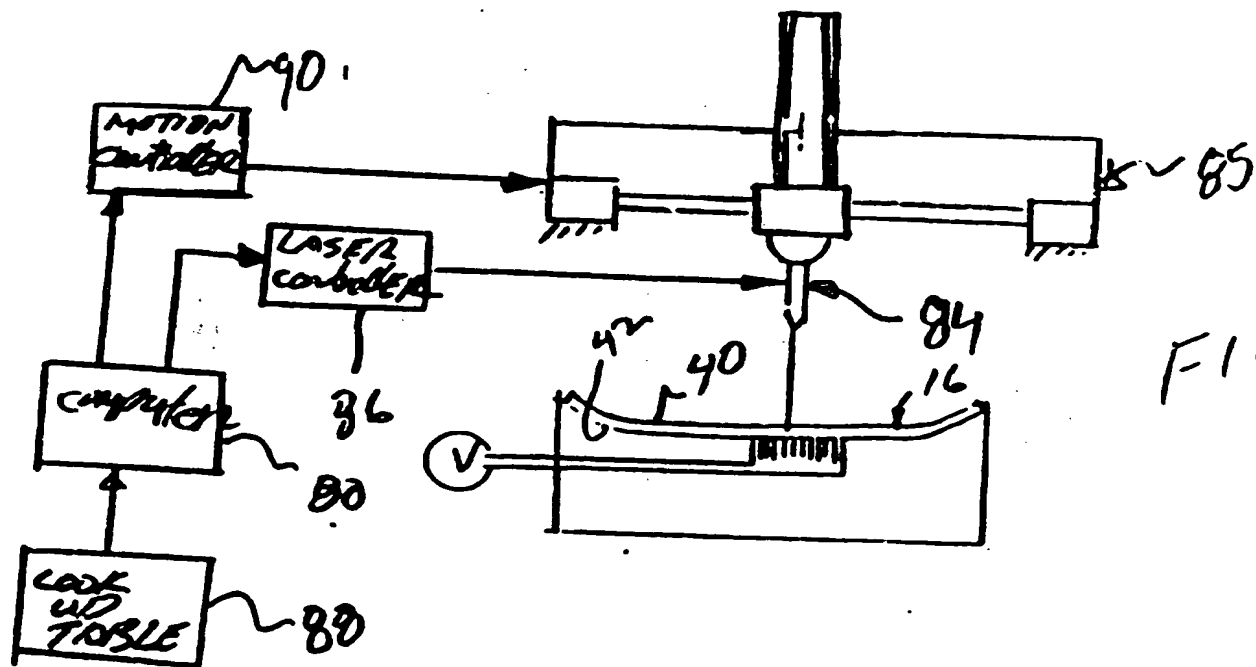


FIG 4C

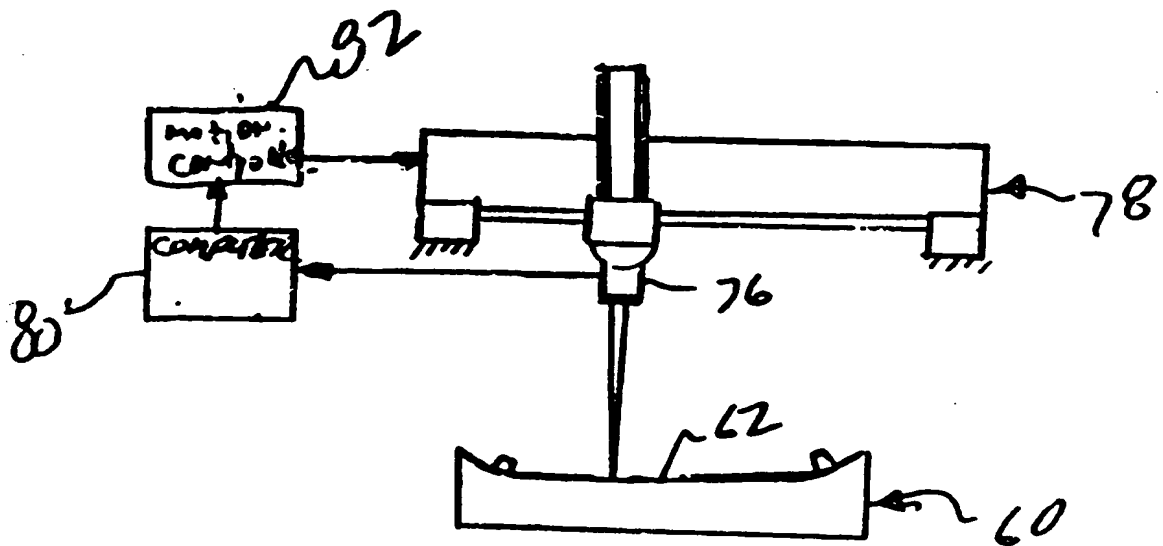
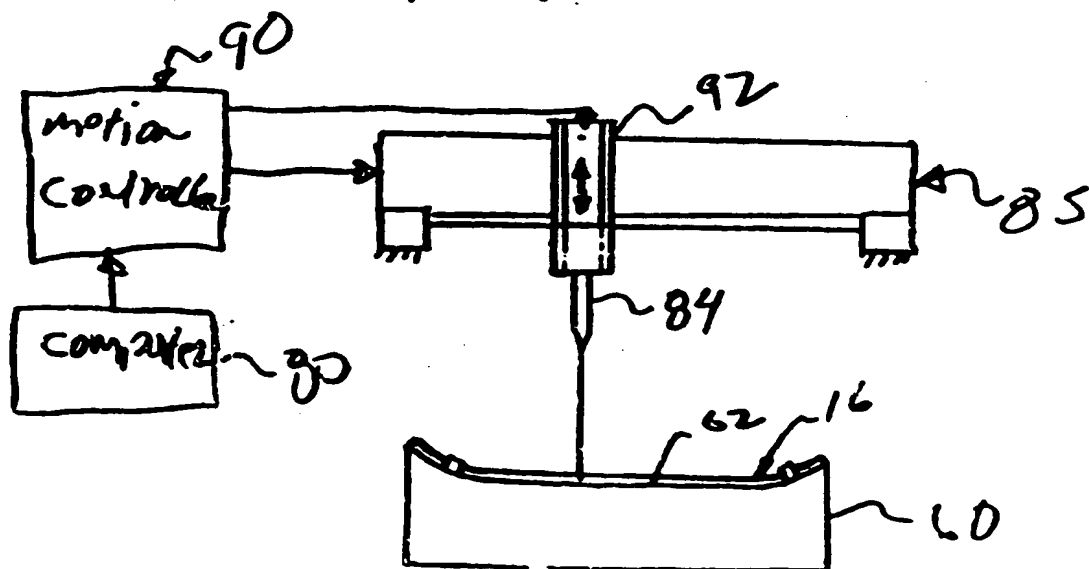
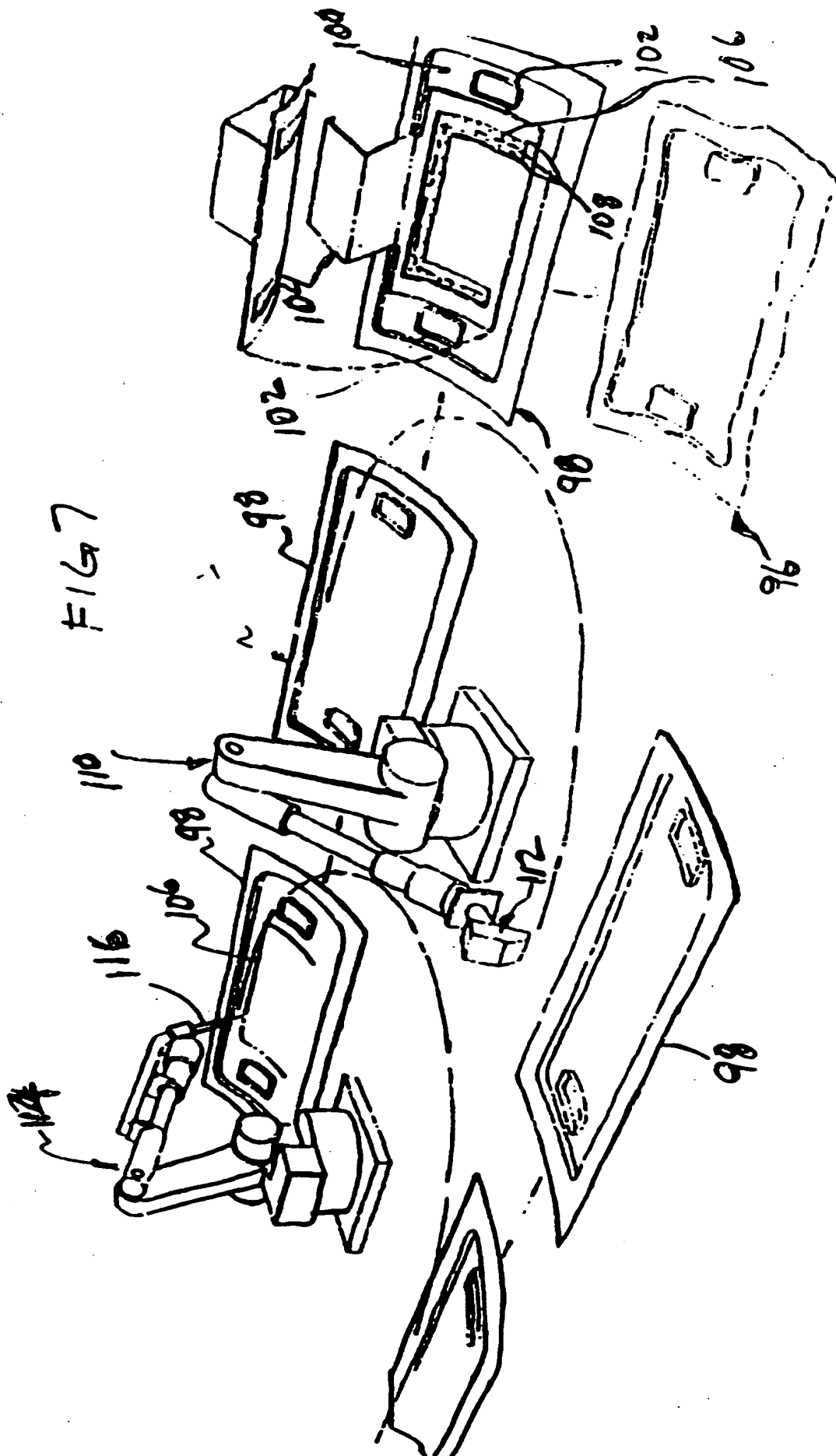


FIG 6

FIG 6A





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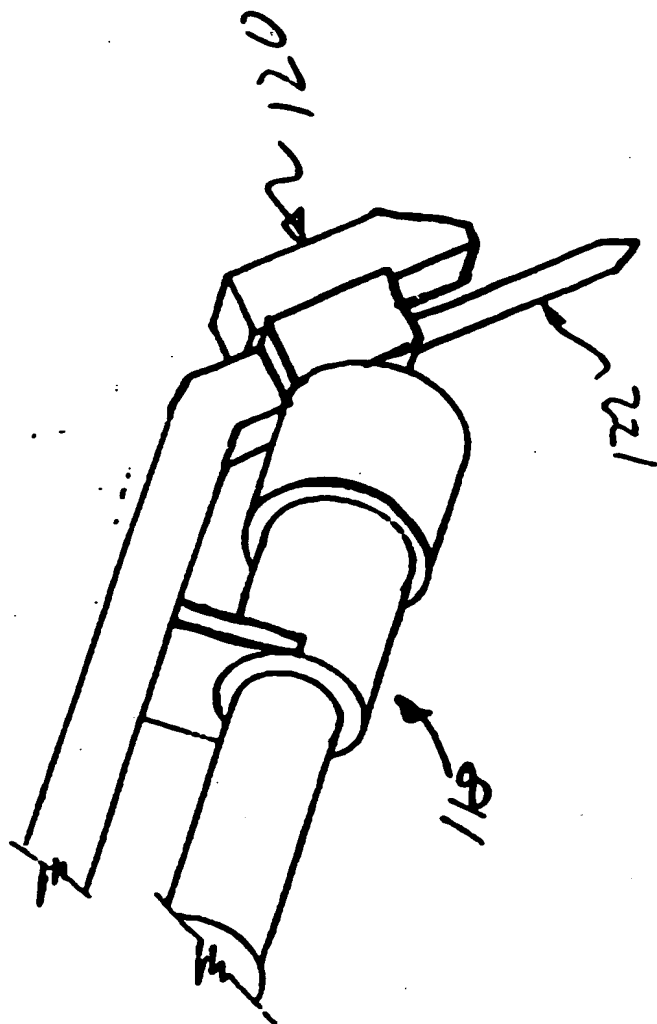


FIG 8

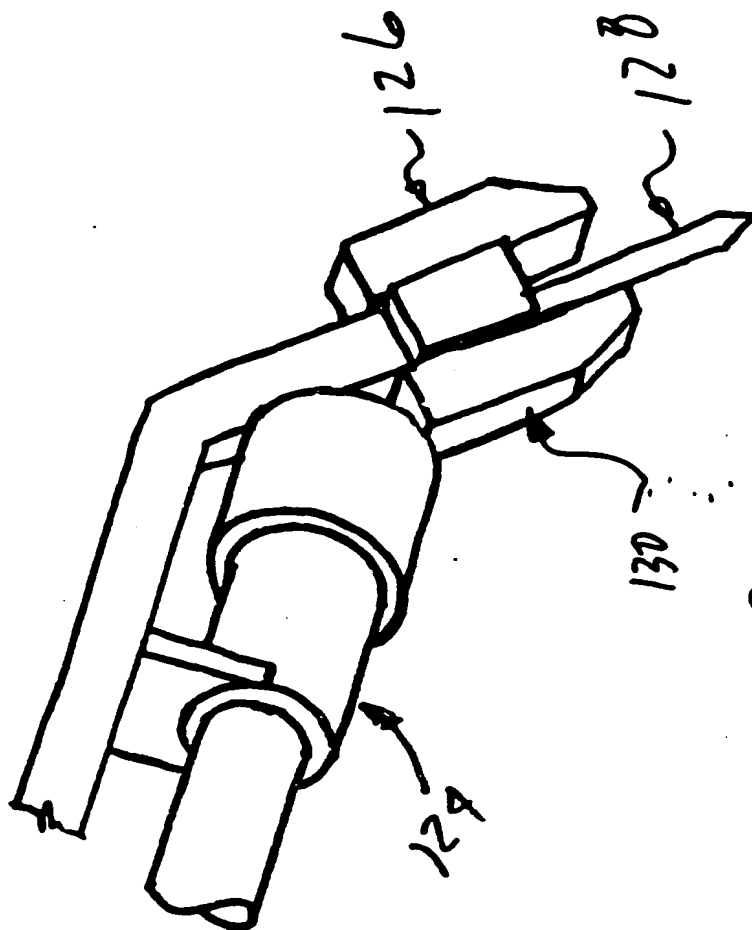


Fig. 9